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(54) Ga As DIODE-PHOSPHOR LAMPS

(71) We, STANDARD TELEPHONES AND CABLES LIMITED, a British Company, of 190 Strand, London, W.C.2., England, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: —

This invention relates to GaAs diode-phosphor lamps and finds particular but not exclusive application in the provision of display devices such as a seven bar array, or other alphanumeric display array, incorporating a number of such lamps on a common substrate.

Gallium arsenide diodes emit infra-red light, but this light can be converted into visible light by using a suitable anti-Stokes phosphor. Normally such a diode is grown by liquid epitaxy, preferably using silicon as a dopant because this is an amphoteric dopant in gallium-arsenide. A trough to contain the phosphor is then etched in the face of the semiconductor material so as to encircle a small area of the junction. The efficiency of such a device is not only limited by the poor efficiency of an anti-Stokes phosphor but also by the fact that a significant proportion of the infra-red recombination radiation is wasted in that it never reaches the phosphor. One of the factors contributing to this waste is the amount of light radiated at a significant angle to the junction. This invention is concerned with a method of construction which will provide a measure of optical guiding in order to channel a proportion of this otherwise wasted radiation so that it will reach the phosphor and hence be able to make a contribution to the production of useful visible radiation.

According to the invention there is provided a gallium arsenide diode-phosphor lamp wherein the recombination region of the gallium arsenide diode lies in a region of gallium arsenide which is sandwiched between two layers of gallium aluminium arsenide.

The efficacy of the gallium aluminium arsenide layers in providing the desired channeling effect relies upon the fact that it has a lower refractive index than gallium arsenide. There is thus a critical angle at each heterojunction, and light incident upon either of the gallium aluminium arsenide layers at an angle greater than this critical angle is totally internally reflected. This totally internally reflected light is thus trapped in the recombination region of gallium arsenide and is ducted to the perimeter of the region where it can be absorbed by the phosphor.

There follows a discription of a seven bar array incorporating a number of gallium arsenide diode-phosphor lamps on a single substrate, these lamps embodying the invention in a preferred form. The description refers to the accompanying drawings in which: —

Figure 1 depicts a diagrammatic sectional view across the width of one of the bar-shaped lamps of the array, and

Figure 2 depicts a plan view showing the arrangement of the lamps to form a seven bar array.

The method of manufacture involves the growth by liquid epitaxy of four layers 1,2, 3 and 4 upon an n-type gallium arsenide substrate 5; layer 2 is approximately 10 microns thick, but the thickness of the other layers is not critical. The first layer to be grown, layer 1, is an n-type layer of gallium aluminium arsenide having approximately 50 mol% substitution of aluminium ($Ga_{0.5}Al_{0.5}As$). The next layer to be grown, layer 2, is a layer of gallium arsenide. This layer is to contain the recombination region and hence requires a transition from n-type material to p-type material. In the growth of this layer use is made of the amphoteric doping properties of silicon in gallium arsenide. Accordingly while this layer 2 is grown the temperature is caused to fall through the range 910° C to 880° C so that the first part grows in n-type form and the last part in

p-type form with a continuous graduation between them through a compensated region. The third and fourth layers 3 and 4 are respectively p-type layers of gallium aluminium arsenide ($Ga_{0.7}Al_{0.3}As$) and gallium arsenide.

The material is then polished, contact layers 6 and 7 are put on, and standard photolithographic techniques are used to etch a number of channels through all the epitaxially grown layers. These channels delineate small strips 8 of grown material arranged in the form of a seven bar array. The channels are then filled with an anti-Stokes phosphor 9 comprising erbium and ytterbium activators in a lanthanum fluoride matrix material.

WHAT WE CLAIM IS:—

1. A gallium arsenide diode-phosphor lamp wherein the recombination region of the gallium arsenide diode lies in a region of gallium arsenide which is sandwiched between two layers of gallium aluminium arsenide.

2. A lamp as claimed in claim 1 wherein the phosphor is contained in a trough encircling a region of the junction between the diode's regions of different conductivity type.

3. A lamp as claimed in claim 1 or 2 wherein the layers or gallium aluminium arsenide have a 50 mole% substitution of aluminium so that they satisfy the formula $Ga_{0.7}Al_{0.3}As$.

4. A lamp as claimed in any preceding claim wherein silicon is used as an amphoteric dopant is forming the junction between the diode's regions of different conductivity type.

5. A plurality of lamps as claimed in any preceding claim constructed upon a single substrate.

6. A plurality of lamps as claimed in claim 5 and arranged in the form of an alphanumeric display device.

7. A gallium arsenide diode-phosphor lamp substantially as hereinbefore described with reference to the accompanying drawings.

8. An alphanumeric display device substantially as hereinbefore described with reference to the accompanying drawings.

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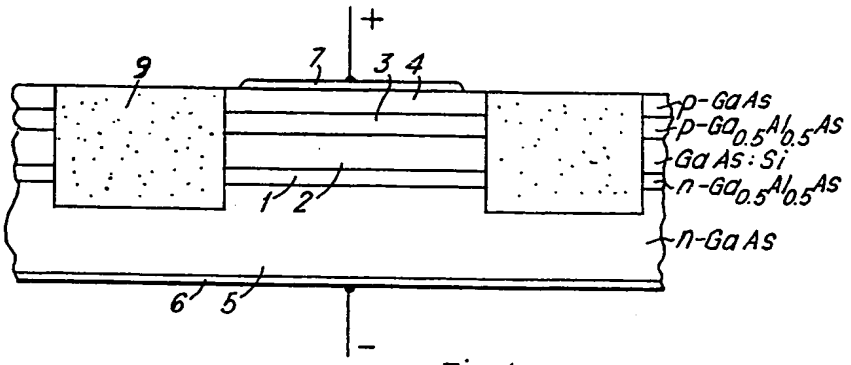

Fig. 1.

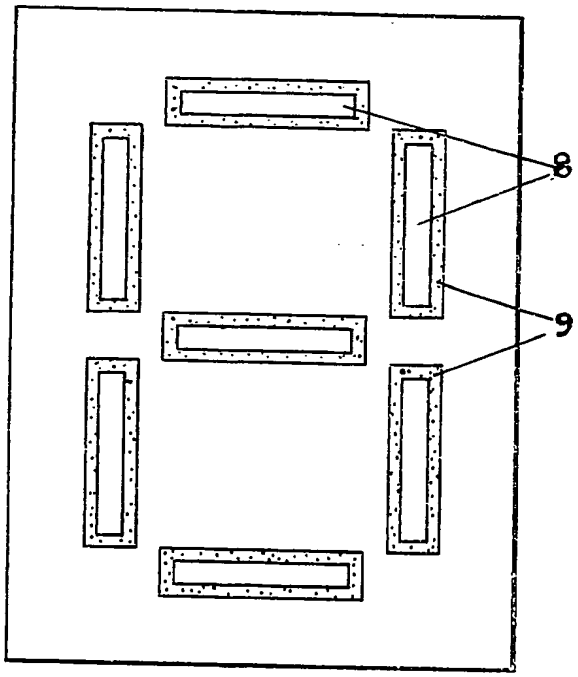

Fig.2